find nothing more substantial than a number of integers which mutely stand and wait for elements not yet discovered, or not yet isolated in as pure a state as may be possible.

I suppose we must view this table, and in fact the whole article, in the light of Prof. Armstrong's dictum,

"that imagination and even sentiment play an important part in chemistry, and that if too narrowly and rigidly interpreted, facts may become very misleading factors."

I do not know that this is true, but I feel convinced that the ruthless treatment which facts receive in this new table is not calculated to further exact science.

I must pass over the doctrine of residual affinity and the view of chemical combination as reversed electrolysis which figure so largely in the article. Their application to facts involves a most intricate discussion. These views have been before the chemical world for many years, and I do not think the measure of acceptance which they have gained warrants the prominence which Prof. Armstrong gives them in a general article.

Lastly, in dealing with the ionic theory Prof. Armstrong begins, it is only fair to say, by giving an impartial account of it, with illustrations of its application to chemical phenomena. He adds to this a reiteration of his own objections to the theory and an exposition of possible alternatives which he thinks preferable. This may be allowable, but I cannot pass over the serious charge which is made, that

"the advocates of the dissociation hypothesis have declined even to consider the objections which may be raised to it from the chemist's side."

I am aware of the historic fact on which this statement is based, but I consider it most unfair to leave the reader of the Encyclopædia article under the impression that the ionic theory is entertained as a dogma by the large number of eminent chemists in whose hands it has been the means of effecting such remarkable advances of knowledge.

I do not wish, of course, to imply that in this article Prof. Armstrong has done otherwise than give an honest account of the state of chemistry as it appears to him, and I affect no claim to compete with him in dictating the true faith. But I do say that the whole article is so imbued with the peculiar opinions of the author as to be the polemic of an individual rather than a description of the state of chemistry as it appears to the vast majority of those who follow the craft. For this reason it does not appear to me to be well suited for an encyclopædia.

ARTHUR SMITHELLS.

SUBMARINES.

Les Bateaux Sous-Marins et les Submersibles. Par R. D'Equevilley, Ingénieur Civil des Constructions Navales, Ancien Ingénieur aux Forges et Chautiers de la Méditerranée. (Paris : Gauthier-Villars, 1901.)

IT is curious to note the difference in the general appreciation of the submarine in England and in France. Here until recently these engines of destruction do not appear to have been taken seriously by our professional guides, and, so far as the public know, but little has been done to prove their value, whereas in France, not only are there many already belonging to the Navy, but public appreciation of their utility is such that engineers will have to make themselves familiar with their history and their present lines of development. A handy little book such as this at three francs is likely, therefore, to find a ready sale.

The first chapter relates to the history of the subject under the heads of the different countries. It is interesting to us to note that the earliest submarine mentioned, *La Hollande*, was constructed on the Thames in 1620 and was worked in some way by oars, greatly to the delight of James I. The English have not done much in this line, nor have they been greatly encouraged by the authorities, for we are told that Johnson, early in the nineteenth century, navigated under the Thames in a submarine, which was confiscated by the Government on the pretext that he was going to deliver Napoleon. The builder of the submarine and of the motor-car seem to have been about equally stimulated.

It is surprising to see how, in almost every country but England, the problem has been attacked by many inventors, France apparently taking the lead.

The conclusion of the second chapter, that "habitability" is the most easy thing to attain, is not what would be expected, nor does it seem quite to agree with the accounts of the exhaustion of the men that have appeared at times in the newspapers.

The description of the view obtained from a submarine is interesting. At the depth of only a few metres it appears as if the boat is at the centre of a great circular hall without a roof, as refraction prevents skylight from penetrating beyond the critical angle. It is interesting to contrast this with the appearance of the earth seen from a balloon. Here the observer, as the effect of perspective, seems to be in the centre of a vast concave bowl. The colour of the water is described as favourable for lighting by the electric arc, as the course can be seen for 50 metres ahead.

Under the head of security, the author offers some rather chilly comfort, for he explains that as the submarine is of necessity of about the same density as the water, if you chance to run on a rock there is very little to prevent your glancing off, whereas with a surface-boat the weight at once prevents its rising in a similar way. It must, however, be remembered that if a liner merely scrapes laterally against quite an insignificant iceberg the plating is ripped off as long as the contact lasts. Of course, in consequence of the higher speed and greater dimensions, inertia is far more formidable in this case, but it is difficult to believe that even a submarine could do much rock scratching with impunity. Lest, however, anyone should become too confident, the author points out that one danger always exists—that of not being able to go up, up, up. For this reason the system always employed in French submarines has much to recommend it. These, even when they descend, retain a considerable buoyancy tending to make them rise, but they only actually descend by the action of horizontal rudders or aqua planes corresponding to the aëroplane of a flying machine. Such an arrangement will not permit of remaining below the surface voluntarily when at rest.

The chapter on the discharge of torpedoes is necessarily disappointing, as the author is unable to disclose information of a confidential nature.

The most interesting chapter is that which deals with the different stabilities on which the successful navigation depends. There can be no stability of buoyancy when totally immersed; the vessel either rises to the surface, or if it is ever so little heavier than the surrounding water it descends with ever-increasing velocity as the shell becomes compressed until the bottom is reached. When, however, the ship is moving longitudinally, the horizontal rudders determine the rise or fall. The author has no word of commendation for the method of rising or sinking by means of vertical screws.

After discussing shortly the interesting question of lateral stability when floating and when immersed, the author proceeds to the explanation of the effect of the position of the horizontal rudder on the good behaviour of the ship when diving. It seems that the old contest between rear and front steering wheels in tricycles has its counterpart here, and that the front steering, as in the other case, leads to more steady and certain results. The stability of direction depends upon there being plenty of length with fine lines aft. We are told that the submarine of the French Navy, after a run under water of several miles, can come to the surface again on exactly the same course as that which was followed at first.

A series of chapters on motors—steam, electric, petrol—and on tactics bring the author to his conclusion, which shows that he and the French Navy are in grim earnest, and that in his opinion so powerful and insidious a weapon will make naval warfare too terrible to be tolerated any longer. However confident the author may be, and whatever the truth may be, there is in this country much scepticism as to the power of the submarine, as will be gathered from an excellent article in the current number of *Whitaker*, p. 694. C. V. B.

THE DYNAMICAL FOUNDATIONS OF THERMODYNAMICS.

Elementary Principles in Statistical Mechanics. By J. Willard Gibbs, Ph.D., LL.D. Pp. xviii + 207. (New York: Charles Scribner's Sons; London: Arnold, 1902.) Price 10*s.* 6*d.* net.

WHERE a branch of science has been approached exclusively from the deductive side or exclusively from the experimental side, it is far easier to form a correct estimate of our state of knowledge in it than is the case where experimental and deductive methods have been continuously worked side by side. The study of rational dynamics has afforded excellent mental training for those who have made the greatest marks in the world as physicists, notwithstanding the fact that the conclusions arrived at in rational dynamics are in direct contradiction to ordinary experience. Thus it is impossible to verify experimentally that the times taken by *particles* to slide down *perfectly smooth* chords of a vertical circle are equal, and the phenomena of Nature are far too complicated to allow of an experimental test of the velocity with which a boy would have to throw a cricket ball *in vacuo* in order to give it a horizontal range of 200 yards. In the study of thermodynamics, on the other hand, where the experimental has preceded the deductive treatment, as has been the case ever since Joule discovered the so-called mechanical equivalent of heat, much confusion and failure to appreciate correctly our state of knowledge have necessarily resulted, and the only way of evolving order out of chaos is to formulate a theory on a purely deductive basis founded on certain hypotheses. The interest of the theory from a physical standpoint will then depend in the agreement or want of agreement between the conclusions of the theory and the results of observation.

In his study of the equilibrium of heterogeneous systems, Prof. Willard Gibbs, starting from the deductive side, gained a point of vantage which has proved of the greatest possible value to the experimental physical chemist. In his present work the same author is to a large extent following in the footsteps of Boltzmann, Watson and other writers, but at the same time he is imparting a great amount of his own originality, both in form and in treatment, to their work. It is impossible to read this volume without feeling that Prof. Gibbs has been to a great extent imbued with the same spirit which led Dr. Watson to produce the second edition of his excellent treatise on the "Kinetic Theory of Gases." This is a valuable feature, for it would be difficult to produce in a small compass a better introduction to the purely deductive study of the kinetic theory than has been given us by Dr. Watson. But Prof. Gibbs has gone further, and has not only discussed the subject at somewhat greater length, but by clothing the investigation in new language, under the title of "Statistical Dynamics," has presented it in a form in which it can be studied quite independently of any molecular hypothesis as a purely mathematical deduction from the fundamental principles of dynamics.

The study of statistical dynamics is based on the consideration, not of a single body or system, but of a very large number of such systems, and such a collection Prof. Gibbs calls an *ensemble*; moreover, in the course of the work it is found necessary to distinguish between *grands ensembles* and *petits ensembles*. The principle underlying the whole investigation is the well-known determinantal relation (corresponding to § 8 of Watson's book) connecting the initial and final values of the multiple differentials of the coordinates and momenta of an *ensemble*. The precise meaning of this relation has always been exceedingly difficult to grasp. It surely adds considerably to our clear understanding of the property to have it now enunciated as the "principle of conservation of extension in phase." A slightly modified form of enunciation gives the principles of conservation of density in phase, and of probability of phase. A further property is that extension in phase is an invariant in that it is independent of the choice of coordinates.

The most interesting distribution of the coordinates and momenta of an *ensemble* is that determined by a probability coefficient of the form $e^{-h\mathrm{E}}$ which is commonly known as the Boltzmann-Maxwell distribution. Prof. Gibbs calls this the *canonical* distribution, and the limiting case of $h=0$ where the coefficient of probability is unity is called the *micro-canonical* distribution. The